Building Concepts and Classifications

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Abstract

In the built environment, an enormous amount of concepts exist. Therefore, it is useful to identify basic definitions of the concepts and put together classifications and thereby create structures, which can give overview. Many different classification systems have been developed during the last fifty years and the primary purpose has been to support data exchange between partners in building construction projects in traditional document based collaboration processes. These processes have changed, new model based design approaches have been developed and, therefore, new demands for classification systems have been raised.

In this paper, it is assumed that building design is performed by modelling and that computer based building models are used as the basis of data exchange. Therefore, the primary focus of the paper is classification in connection with modelling, what is needed and how classifications can support this. A major issue in modelling is the initial identification and definition of model objects. Subsequently, it is assumed that the objects will persist and that they are further detailed.

In relationship with initial identification, it is proposed to develop and use classification of functions in contrast to classification of building elements by function, which is included in all known existing classification systems. This classification can be performed as a clean classification, where each node in the hierarchy expresses a function so that these functions form the structure of the classification hierarchy (taxonomy), i.e. functions and sub-functions. In order to obey this, component type names, e.g. floor, wall, tank, beam, valve and pump, may only be included as examples and primarily at the hierarchy terminals. A draft proposal of classification of functions is developed. For subsequent modelling activities, it may be more useful to classify building components by other criteria. A draft proposal of building component classification is also developed.

Furthermore, a range of primary concepts related to classification is defined and discussed and, on this basis, some considerations about classification are developed. In particular, the fundamental concept function is discussed and defined. As stated, there are multiple definitions of the function concept with relevance to building components and, as a result, the definition is split up in four meanings depending on the situation. As already indicated and in contrast to other theories and standards, the concept building component is defined and used instead of building element.
1. Building Descriptions and Building Models

In building construction, a large amount of concepts are used and for many terms, there is not a common agreement about the definition. In order to avoid any confusion, some of the most basic terms used in the following are defined or explained in appendix A. Some of the terms are further explained in this section in connection with additional terms.

Any kind of description of a building can be regarded as a model, so models play an important role in connection with buildings [Jørgensen 2008]. However, there are some important distinctions to make about models. As illustrated by Figure 1, there are fundamentally two kinds of models: models created by analysis and models created by synthesis [Jørgensen 2002]. Models of existing buildings are models created by analysis and models of non-existing buildings, e.g. buildings to be constructed, are models created by synthesis. Hence, models created by synthesis are normally developed and used in the design and construction phases while models created by analysis are developed for operations and management of the constructed building. Such a model, however, may partly be based on an existing model, if such a model has been maintained in advance.

![Figure 1 – Two kinds of models](image)

Another distinction about models is whether they describe individual buildings or they describe buildings in general. Most often, the backbone in descriptions or documentations of individual buildings is the building structure, i.e. a whole-part structure, where the building is subdivided into components/parts, which again are subdivided into other components/parts etc. down to an appropriate level. This is termed composition and such a structure can be formed in many ways and in general it should be created based on a stated purpose. In different building life phases, the structure and the need for details may be different; so, a suitable description as the basis for construction may not be ideal for the operations and management. In this phase, for instance, detailed description of many basic components like kernels of foundations, walls and slabs may be of minor importance while more detailed descriptions about coverings and building service components may be of greater importance.

General regulations about how descriptions and specifications of buildings should be formed will naturally also include provisions for the structure and the sequence in which description parts should occur. Such regulations or recommendations may be published by certain authorities, associations or organisations and aim at specific categories of buildings. The purpose of creating such regulations should be to standardise building descriptions and thereby to make it easier to share and compare building descriptions between partners.

Often, such regulations are characterised as classifications but, seen from a theoretical point of view, they are not. Although they are of a general nature and they use names, which may be argued to represent classes of components, the overall characterisation is that they
are only about the whole-part structure of buildings. *Classification is something else and more than just identification of classes.*

## 2. General Statements about Classification

The most fundamental term regarding classification is the concept class. However, the concept type is often seen as an alternative concept with the same or similar meaning\(^1\). A useful difference between the two concepts can be defined on the basis of Figure 1: the class concept is used in connection with models created by analysis while the type concept is used in connection with models created by synthesis. Further, classes are considered specified by properties while types are considered specified by attributes. Hence, analytically, it is defined that a class is a set of existing components with certain common properties and it is stated that components belong to classes, are members of classes or that classes contains components. By synthesis view, types are defined by common attributes and components are regarded as instances of types or types are templates for components.

These differences are often not considered clearly; so, by using the two concepts in these two different meanings, the actual context is stated implicitly. By using the terms class and properties, an analysis context is expressed, e.g. where classification is used to embrace data about existing buildings. By using the terms type and attribute, a synthesis context is expressed, e.g. when a classification is used as a basis for modelling, and where components are identified on such a basis.

Further, it is stated that classification is an *abstraction mechanism* by which component classes can be arranged in a hierarchy, termed *taxonomy* [Jørgensen 1998] [Jørgensen 2004] [Smith 1977a] [Smith 1977b]. The most general classes are at the higher levels (root levels) and the most special classes are at the lower levels. This means that, at any node, the sub-classes must be specialisations of the super-class and, in contrast, any super-class is a *generalisation* of its sub-classes. Each sub-class is said to inherit the attributes of the super-class and, in addition, each sub-class must have its own attributes. Classification is the foundation for the paradigm *object-orientation*, which has a general scope but most extensively has been used in software development [Rumbaugh 1991] [Booch 1998].

Composition, as described above, is also an abstraction mechanism, but clearly the two abstraction mechanisms are very different. Classification and composition are sometimes characterised as *orthogonal* to each other. Classification may be very useful in modelling as the basis for identification and creation of components and, when components are created, the composition structure can be created. In this way, both abstraction mechanisms will be used in modelling tasks.

For a selected set of components, multiple classifications can be developed and it is therefore necessary to select a *classification criterion* to determine the nodes of the taxonomy. Hence, different classification criteria result in different taxonomies of the same components. If each node in the hierarchy can express a class according to only one criterion, the classification is *clean* and if multiple criteria are used, the classification is *mixed*. In this case, only one criterion should be used on each level of the taxonomy. A criterion must be selected due to a purpose, so not all classifications (included clean classifications) may be useful or relevant for a selected purpose.

Ideally, components belong to only one node in a taxonomy, but very often components can be characterised by multiple nodes. In this case, it is often possible to identify one of the

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\(^1\) In the building construction industry, the concept type has often a specific meaning, i.e. a technical solution for building components.
nodes as the primary characterisation, i.e. the primary class. The other classes are secondary classes.

Taxonomies can give overview and make it easier to identify something new. By having classifications in advance, this can support finding and selection among presented alternatives as illustrated in Figure 2. The purpose and practical use of taxonomies for identification of building components may be very different in different life phases of a building. In the very early phases, a primary purpose could be to give inspiration about what functions should be required or provided by the building or by building components.

![Figure 2 – Use of classifications (taxonomies) in modelling and model detailing](image)

In building modelling, selection of new building model components is necessary many times. At first, such components may be major model components and only roughly specified, i.e. no internal structure is defined and only few attributes are determined. Later on, the model components are detailed by two dimensions: specification and structure. Specification detailing concerns further identification of attributes and structure detailing includes subdivision into sub-components, ultimately down to building products, building articles or building materials. Thus, key issues about data exchange in connection with modelling are to formulate requirements about the degree of model detailing. For instance in the maintenance phase, the need may be to detail further compared to what is needed for construction. Important data in this phase about components could be e.g. instructions for operations and maintenance. Consequently, it should be possible to support all levels of detail by taxonomies.

With databases of existing component types, software applications may be able to create and display different catalogues. Users will thereby have alternative ways to find and select components. This approach can be followed, when each component type has a set of properties and these have values assigned. If an overview of the properties is given, the classification can be based on this. If multiple taxonomies can be created for the same set of component types, multiple alternative overviews can be provided. A property can be selected for each level, the occurred values of the properties can be analysed and then classes from these values can be identified. By setting some rules, such a classification can even be performed automatically each time a user selects a property.

Observe that such an approach can reduce the demand for classification and, on the other hand, increase the importance of identification and systematic definition of attributes of components. It also indicates that classification and selections based on attributes can be combined, i.e. a primary overview can be established by classification and details can be selected via attributes. If for instance a material attribute is specified for a class of components, it may provide the basis for selection in favour of a classification criterion.
3. Functions of Building Components

As the function concept is the basis for many decisions in building construction, it is important to establish a definition of this concept. In appendix B, various meanings of the concept are listed from the Encarta Dictionary. Similar meanings are available in Webster Dictionary. From this foundation, the function concept is further discussed in relationship with systems thinking in appendix C.

Functions of building components are important through the whole life time of building construction projects but most importantly in the early project phases (a new building or renovation of an existing building), where requirements are identified and specified – function modelling [Kiviniemi 2005] [Jørgensen 2008]. In the building modelling phase, building components are identified to provide the required functions. If parts of a building need to be renewed or extended at a later time, functions play the same important role.

Functions of building construction components are initially considered without regard to any technical solution to perform the function and for each component, there may be several solutions. Furthermore, a technical solution can be produced on site, manufactured on other locations or purchased as a building product. Modelling by use of a traditional CAD system is oriented towards geometry and supports most often selection of model components from a library.

Construction components have many functions but, when they are initially identified, they are often justified by only one or a few functions. A window, for instance, has normally at least two primary functions, to draw natural light into a room and to give view from the room. However, a window has also an insulation function, an acoustic function and a ventilation function (if it can be opened). In principle, a building component may be identified and created solely on the basis of its primary function and before its geometry is determined.

Spaces can also have many functions because they can have multiple uses and many concurrent activities can take place in each space, e.g. social living, sleeping, work, personal care, and storage. For spaces in particular, the two different approaches analysis and synthesis form two alternative ways to identify functions of spaces. One is by what they are actually used for (analysis view) and the other is by what the intended use is (synthesis view). An often used building design approach is to identify the primary space function before sketches of the building form are developed. Consequently, it is useful to create model objects of spaces before the shape and position is determined.

Some functions of spaces must be considered abstractions, because it must be remembered that such functions are actually provided by e.g. equipment, installations, construction components or furniture in the space or related to the space. Some examples are: to offer comfort by heating/cooling, to shield from weather or noise, to protect against theft/robbery, to provide floor or volume, and to offer internet access.

4. Existing Classification Systems

Various classification systems have been developed by different nations and institutions, e.g. SfB, BSAB in Sweden [BSAB 1998], Cl/SfB, Uniclass in UK [Uniclass 1997], Building 90 in Finland and OmniClass in North America [OmniClass 2006]. In Scandinavian, the SfB classification system was introduced already around 1950. In Sweden, further developments took place over many years and the current system is BSAB 96 [BSAB 1998]. Similarly, the SFB/UDC was introduced in UK around 1960 and was revised in 1976 as Cl/SfB. This system has been succeeded by the Uniclass system in 1997. In Denmark, a rather new proposal Dansk Bygge Klassifikation (DBK) has been published in 2006 to replace the existing SfB
Many existing classification systems are referring to the standard ISO 12006-2, Organization of information about construction works – Part 2: Framework for classification of information [ISO 2001]. In this standard, the concept element is introduced as a foundation for classification. The concept is defined as “a construction entity part which, in itself or in combination with other such parts, fulfils a predominating function of the construction entity”. This concept represents an abstraction and underlines that, in the initial life phase of a building model component, only functions are considered and e.g. technical solutions, material possibilities and construction methods are not taken into account.

OmniClass Table 21 Elements (Including Designed Elements) is organized by elements’ implied functions and Uniclass Table G covers elements of buildings. BSAB 96 deals with the element definition and differs from the ISO standard. It defines a slightly different concept, where the phrase "in itself or in combination with other such parts" is omitted [Ekholm 2003] and, consequently, it is explicitly stated that only the main function of elements is used as basis for classification. To use function or main function as a classification criterion for building components is questionable. As stated, every building component has many functions and could potentially occur multiple times in a taxonomy. To focus on the main function of each building component limits this problem but the main function of a building component may depend on the actual location in the building and the relationships with other building components. Consequently, a taxonomy of building components structured by use of the function criterion will not provide a unique overview and will be difficult to use.

As previously stated, building components can be decomposed and assembled and this is clearly underlined in OmniClass in relationship with Table 21 and this is also highlighted in connection with BSAB 96. The first steps of modelling often regards major and often composite components but such components create major problems regarding classification by function because they represent multiple functions and, thus, identification of main functions may be difficult. Otherwise, such element classes may occur at multiple positions in classification taxonomies. In BSAB 96, a separate entry is reserved for classification of composite elements and systems as a separate classification compared to elements. Consequently, there are conflicting requirements regarding modelling and classification.

Besides the problem of including composite components in the classification, it is a key question whether the existing classification systems conform to the theory of classification or not. There are some indications that the two abstraction mechanisms classification and composition are mixed up in the tables. In OmniClass Table 21, a few examples show that it is done at lower levels of the tables, probably in order to simplify and to increase the usability, e.g. 'Subgrade Walls (includes: Wall Supports)'. At an upper level of the table, the divisions of 'Structure' into 1) 'Substructure', 2) 'Superstructure and Enclosure', 3) 'Enclosure', 4) 'Interior' and 5) 'Signage' could easily signify a division by composition (a whole-part structure) but it is important to interpret the division must as sub-classes.

In contradiction to this, the building components table of the new Danish DBK system must be categorised as not being a classification system but instead the division is made as a whole-part structure. This has recently been concluded in an evaluation report [Ekholm 2011]. The top division of the table is by systems: 'Site system', 'Foundation system', 'Wall system', 'Slab system', 'Roof system', 'Water system', etc. and for example the 'Wall system' consists of 'window panel', which again consists of 'window', etc. Functions of components are listed in a sub-table.

A major issue about all the classification systems is that the classification criteria are not clearly stated. In case that functions are the criteria, these are only expressed indirectly, e.g. 'substructure' and 'superstructure'. Furthermore, there are many examples, where mixed classification is performed, i.e. multiple classification criteria are used. In BSAB 96,
the above mentioned separate entry for composite elements is one example. However, this table is formed by levels, where different classification criteria may exist for each level. For instance, several entries are characterised as completion element and this is not a division based on element function. Similarly in OmniClass, there are many examples, where function is not the criterion, e.g. divisions under 'superstructure': 'floor construction', 'conveying systems', 'bridge construction' and 'tower superstructure construction'. Further, the position 'conveying systems' is subdivided into e.g. 'vertical', 'horizontal' and 'sloped' transportation, which is rather a form criterion.

Overall, the existing classification systems are primarily oriented towards physical building components, which are identified from a geometrical point of view. New needs in relationship with building modelling are not incorporated. In such processes, other approaches for identification and creation of building model components may play a prominent role.

The issues, which have been discussed above, have created the idea that the subject should be turned upside down. Instead of classifying building components by function, it would be better to classify functions and attach building component types/classes to function nodes. Referring to Figure 2, the idea is that the first taxonomy to be used in a modelling approach should be a taxonomy of functions.

5. Classification of Functions

In this section, an attempt is made to form a clean classification by use of function as the classification criterion. The aim is to provide a taxonomy, which can give overview over the most important functions, which can be used to first-time identification of building components in building models. This identification is in contrast to selection of components by geometry, e.g. by a CAD system, where the determining functions of the components are not explicitly stated. When each component is identified, it can be created as a model component and, as a consequence, attributes for the selected function can be created also. Consequently, there is a clear distinction between modelling before and after the identification of components.

As soon as a model component is created, a stepwise specification of further attributes and of sub-components commences as a fundamental modelling approach. This approach may open for other needs of classification and eliminates partly the need for the concepts element, designed element, and work result in ISO 12006-2.

The following taxonomy identifies a number of functions organised in levels and each node in the hierarchy expresses a function class and the emphasis is put on identifying appropriate functions on all nodes. Because only function is used as the classification criterion, it is possible to combine classification of space functions and classification of building component functions.

At the lowest levels, names of component classes at listed as examples of classes of components, which can provide the function of the node. Observe that these component classes (listed in brackets) are not included in the taxonomy but represents only relationships to component classes. As a consequence and because each component can have many functions, the related component classes can occur multiple times in the taxonomy. If a component is identified and created, the taxonomy can also be used to identify and attach further functions to the component.

The proposal is made just as an illustration and must not be considered a complete classification.
Provide built environment for human activities

- Provide space (for...) (applied to spaces)
  - Living
    - Social living/sitting
    - Eating
      - (Dining rooms)
    - Communication
    - Relaxation
      - TV viewing
      - Radio listening
      - Reading
    - Sleeping
      - (Bedroom)
    - Creativity
    - Performance
      - (Studios)
    - Work
      - Cooking
        - (Kitchens)
      - Administration
        - (Offices)
      - Personal care
        - (Bath rooms)
      - Personal fitness
      - Passing (to/from/between)
        - Entrance/exiting
        - (Entrées / entrance halls)
        - (Corridors)
      - Elevate/lower
        - (Staircases)
        - (Lifts/elevators)
        - (Escalators)
    - Containment
      - Storage
      - Equipment containment
      - Protection from people
      - Garbage disposal
      - Spaces
        - (Storeys)

- Provide physical environment (for...) (applied to construction components)
  - Strength (indispensable, distinctive primary)
    - Load supporting/distributing (including user loads)
      - (Suspended floors)
      - (Slabs)
      - (Beams)
        - (Rafters – Dk: spær)
        - (Bottom chords – Dk: spærfod)
        - (Purlins – Dk: ås)
        - (Lintels – Dk: Overligger)
        - (Roof trusses – Dk: spærfag)
        - ...
      - (Balconies)
(Roofs)

Load bearing

(Footings)

(Walls – heavyweight walls)

(Columns)

(Posts)

(Piles)

Shielding

(Walls – lightweight walls)

(Curtain walls)

(Solar screenings)

Insulation

Space division

(Walls/partitions – Dk: skillevæg)

(Accordion walls – Dk: foldevæg)

Space connection

(Openings)

(Doors)

(Hatches – Dk: luge)

(Staircases)

(Ladders)

(Transport)

(Lift/elevator)

(Escalator)

(Ramps)

(Bridges)

Space expansion

(Bay windows – Dk: carnap)

(Dormers – Dk: kvist)

Opening for light/air

(Blanks/voids)

(Windows)

(Trapdoors – Dk: loftsluge)

(Window units – Dk: vinduesparti)

Servicing (installations)

Heating

(Distributing)

(Pipes)

(Convection)

(Emitters – Radiators/convectors)

Production

(Boilers)

Exchanging

Cooling

Ventilating
The primary partition is between functions of spaces and functions of building components and, within each of these branches, additional levels of division are proposed. A major advantage of the taxonomy is that, for each function, a range of attributes can be identified and attached to each function node. These attributes clearly underline the importance of selection of functions as the basis of identification of component types. In fact, to establish a list of attributes specific for each function would ease the work with identification of requirements and specification of models for testing and simulation.

At each leaf node of the hierarchy, examples of building component types are listed in order just to indicate which components can provide the specific function. Because these building component types are secondary to the classification, it creates no problem that some component types can occur multiple times in the taxonomy.

As underlined, the taxonomy must not be regarded as a complete classification. There may be better proposals and additional sub-classes may be inserted.

As stated, this taxonomy may be useful as inspiration for first-time identification and creation of building model objects and on the basis of required functions. By creating a clean classification, the taxonomy is relatively easy to use. Each function is only represented once and there is no confusion about how to step down in the hierarchy. When a model object is created, the primary function can be attached to the object. One example could be function for 'passing (to/from/between)' and more specifically for 'elevate/lower'. Another model object could be for 'servicing' | 'heating' | 'production'. Subsequently, additional

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2 To identify attributes based on functions is comparable with the use of IFC property sets.
functions can also be attached. Each time a function is attached to the object, the defined attributes can also be attached. When such functions are determined, it will be possible to select a type of building components – for the stated examples e.g. a staircase and a boiler respectively – and appropriate contained attributes can be specified, e.g. geometrical attributes.

A major advantage of this approach is that space model objects and building construction components can be identified and created in parallel or as suited otherwise and this is in contrast to the support from many CAD software products. Instead, the presented approach can easily be supported by another kind of software.

6. Classification of Building Components

When building components have already been identified by functions, a subsequent modelling phase will include tasks, where each model component needs to be further specified and detailed and e.g. the building component type and subsequently a specific technical solution must be determined. In this process, a taxonomy of building components may be useful for selection of alternatives.

In general, it is important that the construction partners can exchange information about building components and various taxonomies of building components may support this as illustrated in Figure 3. According to ISO 12006-2, classifications of designed elements, work results and products would be useful. It may be useful to have multiple classifications of building components but it would of cause be simpler, if one superior taxonomy could satisfy the needs for detailing. As stated, a taxonomy of building components will be necessary but a taxonomy of products will also be useful and producers of such products can, with reference to this taxonomy, publish information about the products. This would enable designers, constructors and other consumers to use the taxonomy to find alternative products. Examples of such useful information are detailed product description, instructions for handling and assembly of components, instructions for maintenance, warranties, prices and cost values.

In the following, a taxonomy of building component types is proposed and, for modelling purposes, the content of the taxonomy will preferably be building component models. As stated, the aim is to support the specification and detailing process by providing overview over alternative technical solutions. In this process, one or multiple functions of each model

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Figure 3 – Use of taxonomies with different content at different modelling stages
component is already identified and possibly specified. Consequently, it may be suitable to use other classification criteria than function.

As stated previously, a mixed classification is performed when multiple classification criteria are used – in contrast to a clean classification, where only one criterion is used for the entire taxonomy. Obviously, there are many ways to mix classification criteria and sometimes classifications can be messy. However, a systematic mix of classification criteria can improve the usability of a classification and, ideally, only one criterion should be selected for each level of a branch of the taxonomy.

The proposed taxonomy should include all kinds of building components, but not building materials, building articles or those building products, which are considered independent of their application in buildings. The first level divides building components into classes of major different categories: building construction components, building service components, equipment, fixtures and furniture. Thereby, the classes are rather well oriented towards the different construction disciplines. The second level of building construction components is divided into primary components, supplementary components and completion components. This division is selected in order to be well related to the sequence in which the components will be inserted in the building, first the basic components, next the supplementary components and finally the completion components. The second level of building service components is divided into plumbing components, electrical/electronic components, complex plants/units and systems. A few examples of attributes are listed in parenthesis and marked by 'att'. Each attribute is inherited to lower levels. At the bottom levels of the hierarchy, specific component type names are inserted to illustrate the content. The division is suitable for modelling and is comparable to the SfB and CI/SfB classification systems.

The following table includes definitions and explanations of selected building component types.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition and explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building component</td>
<td>General concept for all parts of a building. Building components are either spaces or construction components.</td>
</tr>
<tr>
<td>Space</td>
<td>Spatial delineation. A space is bounded physically or notionally. In general, building spaces are divided into two complementary kinds of spaces, user spaces, which are utilised by the users, and construction spaces, occupied by the construction components.</td>
</tr>
<tr>
<td>Elementary component</td>
<td>Building component considered not to be subdivided.</td>
</tr>
<tr>
<td>Unity/device/plant</td>
<td>Building component, which is divisible but normally handled as a whole.</td>
</tr>
<tr>
<td>Building construction component</td>
<td>Solid material part of a building.</td>
</tr>
<tr>
<td>Building services component</td>
<td>Part of building services.</td>
</tr>
<tr>
<td>Plumbing component</td>
<td>Building service component for flow of liquids or gasses.</td>
</tr>
<tr>
<td>Electrical/electronic component</td>
<td>Building service component, which consumes electricity or which is used for distribution of electricity.</td>
</tr>
<tr>
<td>System</td>
<td>Assembly of components.</td>
</tr>
</tbody>
</table>

*Table 1 – Concepts regarding building component types*
Observe that the component types in the following taxonomy are defined regardless of composition. Composites/assemblies/systems are included in the taxonomy as well as sub-components. This solves the problems from using function as the classification criterion.

The proposal is made as an illustration of how the principles can be used and must not be considered a complete classification.

Hierarchy 2 – Taxonomy of building component types (not classified by function)

Building component

- Space (not further classified)
- Building construction components
  - Construction unity
    - Opening filling
    - Door
    - Window
    - Gate
    - Gate
    - Hatch
    - etc.
    - Staircase flight
    - Staircase landing
    - Staircase
    - Ramp
    - Roof truss/rafter
    - Chimney
    - etc.
  - Elementary component, construction
    - Batten
    - Post
    - Plate
    - Membrane
    - Foil
    - Paint
    - etc.
    - Strip
    - Tile
    - etc.
  - Construction structure
    - Basic component
      - Foundation construction
    - Wall
    - Floor slab
    - Beam
    - Column
    - etc.
    - Addition
      - Dormer
      - Bay window
      - Balcony
      - Spire
      - etc.
    - Floor
    - Ceiling
    - Roof
    - Bridge
. . . . Tunnel
. . . . Bath cabin
. . . . Building wing
. . . . Building section
. . . . Building etc.
. . . Building services component
. . . . Plumbing component
. . . . . . Plumbing unity, device
. . . . . . . . Container
. . . . . . . . Exchanger
. . . . . . . . Convecter, plumbing
. . . . . . . . Pump
. . . . . . . . Compressor
. . . . . . . . Filter unit
. . . . . . . . Well
. . . . . . . . Manhole
. . . . . . . . Spurt
. . . . . . . . Tank
. . . . . . . . etc.
. . . . . . Elementary component, plumbing
. . . . . . . . Pipe
. . . . . . . . Fitting
. . . . . . . . Terminal, pipe
. . . . . . . . . . Tap
. . . . . . . . . . etc.
. . . . . . . . Terminal fitting
. . . . . . . . . . Sink
. . . . . . . . . . Diffusor
. . . . . . . . . . etc.
. . . . . . . . Wash
. . . . . . . . Toilet
. . . . . . . . Bath top
. . . . . . . . Valves
. . . . . . . . Filter
. . . . . . . . Meter, plumbing
. . . . . . . . Gasket
. . . . . . . . etc.
. . . . . . . . System, pipe
. . . . . . . . . . Plumbing system
. . . . . . . . . . Pump system
. . . . . . . . . . Waste water drainage system
. . . . . . . . . . Sprinkler system
. . . . . . . . . . Fresh water distribution system
. . . . . . . . . . etc.
. . . . Electrical/electronic component
. . . . . . Electric unity, device
. . . . . . . . Convecter, electric/electronic
. . . . . . . . Controller
. . . . . . . . . . Access controller
. . . . . . . . . . etc.
. . . . . . . . Transformer
. . . . . . . . Electricity meter
. . . . . . . . Display
. . . . . . . . Cooker panel
. . . . . . . . etc.
. . . . . . Elementary component, electric/electronic
. . . . . . . . Wire
. . . . Terminal, electric/electronic
  . . . . . Switch
  . . . . . Socket outlet
  . . . . . Power point
  . . . . . etc.
  . . . . Sensor
  . . . . Fuse
  . . . . Lamp
  . . . . etc.
  . . . Electric system
  . . . . Alarm control system
  . . . . Access control system
  . . . . Lightning system
  . . . . Aerial system (US: antenna system)
  . . . . AV-system
  . . . . etc.
  . . Installation plant/unit
  . . . Heater
  . . . Boiler
  . . . Lift
  . . . Escalator
  . . . Refrigerator device
  . . . Shower cabinet
  . . . etc.
  . . Building services system
  . . . Heating system
  . . . Ventilation system
  . . . Air condition system
  . . . Transport system
  . . . Refrigerator system
  . . . etc.
  . Unity, general
  . . Accordion wall
  . . Ladder
  . . Banister
  . . Furniture
  . . . Fixture
  . . . . Cabinet
  . . . . Shelves
  . . . . etc.
  . . . Equipment
  . . . . Vacuum cleaner
  . . . . Refrigerator
  . . . . Television set
  . . . . Computer
  . . . . etc.
  . . . Piece of furniture
  . . . . Table
  . . . . Chair
  . . . . etc.
  . . . . Curtain
  . . . . etc.
  . . . etc.
  . Elementary component, general
  . . Door handle
  . . Lock
  . . Hinge
  . . Carpet
As stated, this taxonomy of building components can be used as the underlying structure for sharing and exchange of data about components of the class. This means that data of different kind can be attached to each node and used in subsequent detailing work. A special issue is then about how to relate this taxonomy to IFC classes. All relevant IFC classes (sub-classes of IfcBuilding) will occur in the hierarchy and, consequently, modelling tools can be based directly on IFC.

It is important to state that relationships can be established between taxonomies (illustrated in Figure 4). Actually, the examples indicated in Hierarchy 1 can be seen as results of the relationships between the function taxonomy and the component hierarchy. When a model object is initially created by selecting a main function, a component type can be selected via the relationships, i.e. a set of component types can provide the function. For the function ‘passing (to/from/between)’ | ‘elevate/lower’, mentioned above, related sample component types could be staircases, lifts/elevators or escalators and, similarly, for the function ‘servicing’ | ‘heating’ | ‘production’, boilers could be referenced.

The reverse relationships are also very useful. They will show, which functions are considerable for specific component types. Consequently, if a component type is selected in the component taxonomy, relationships to functions would indicate, which secondary functions could be selected. This would be important in order to add attributes to each component for further specification.

Similarly, very useful relationships between the component taxonomy and the product taxonomy could be established. Each component type could refer to a set of products, which could replace the component.

![Figure 4 – Relationships between taxonomies support efficient specification and detailing processes](image-url)

### 7. Modelling Approach

When building models are created, specific building components are selected and related to each other. The individual building components can be seen as *instances* of the component classes, which are included in the taxonomy above. For each component, a type is selected, the component is created and values are assigned to the attributes of the component.
Besides the ordinary model object attributes, which can carry numeric values, text values, logical values, etc., attributes can also be used to represent relationships between objects. The most simple relationship attribute is the reference attribute, which can be assigned a link to another object, a one-to-one relationship. Another relationship type is the collection, which in short is a one-to-many relationship. This relationship can at a higher abstraction level also be represented by an attribute, hence a collection attribute.\(^3\) An example of the use of these kinds of attributes is shown in Figure 5. Reference attributes are represented by single headed arrows and collection attributes are represented by double headed arrows. As a special form of the reference attribute, it can refer to external data, for instance via data base entrances or web addresses.

As already stated, numeric attributes for one or more functions can be attached when functions are selected from the function taxonomy and other attributes can be provided, when the component type is selected from Hierarchy 2. If further relevant data are attached to building component types in the hierarchy and proper attributes are available, these data may be transferred directly to the model objects. Other sorts of data may be linked to the model components through relationship attributes with external references.

In order to support an efficient modelling approach, modelling tools must have the hierarchies implemented. They must also have libraries of component types and Hierarchy 2 will be suitable as a common overall structure, i.e. for manual selection. Tool specific libraries may be further detailed in order to provide a wide range of solutions.

Supported by an appropriate modelling tool with implementations of these taxonomies, an outline of a modelling approach would be:

1. Define the needed types of space model objects by selecting from Hierarchy 2 and add its main function by selecting from Hierarchy 1. Add additional functions from Hierarchy 1 and attach function attributes for specification.
2. Define types of building construction model objects by selecting from Hierarchy 2. Model the structure of the component types and, for each model object, select via the relationship to function types of Hierarchy 1 the most important functions and attach function attributes for specification.
3. Create instances (with position and geometry) of the defined space object types and building construction object types.

\(^3\) For the sake of simplicity, only these two types of relationships are stated.
4. Select appropriate data, technical solutions, instructions, etc. via references to entries in Hierarchy 2 and possible external references (catalogues, databases, etc.).
5. Via the relationships between component types in Hierarchy 2 and the product taxonomy, specific products may be selected.

Some tasks may be performed in another order or in parallel.

It is not considered, which actors of a building design project should carry out which tasks.

In order to illustrate in further detail how classification can be used in building construction projects, a classification usage scenario is presented in appendix D.

### 8. Composition of Building Components

As previously stated, modelling tools create **model objects** and **relationships between the model objects**. If an IFC representation is generated, an overall spatial structure must be included: Project – Site – Building – Storey etc. To this structure, spaces and construction components can be related. A rather simplified illustration of this shown in Figure 6 based on a small building model example.

![Building Model Representation in IFC](image)

*Figure 6 – IFC representation of building model (simplified example)*
Based on these relationships, different access paths are available for navigation to the components and typically these access paths can be used to organise different composition hierarchies.

For example, the space model objects can be organised in the more general structure illustrated below.

**Hierarchy 3 – Sample space composition hierarchy**

**Building site**
- Exterior space (spaces surrounding the building)
  - Drive
  - Garage
  - Entrance
  - Garden
  - Front
  - Back
  - Upper
  - Lower
- Terrace
- Interior space (spaces within the building)
  - Basement
  - Rooms
  - Ground floor
  - Shared rooms
  - Entrance hall
  - Stairway
  - Lift
  - 
  - Apartment A
  - Rooms
  - Hall
  - Family rooms
  - Dining room
  - Kitchen
  - Living room
  - Bed room
  - Bath
  - 
  - Apartment B
  - Rooms
  - 
  - First floor
  - 

It can be observed that the division of spaces into external and internal spaces leave the spaces, occupied by the construction components as the remaining complementary spaces.

The individual construction components are instances of the component classes in the taxonomy in hierarchy 2 and structures of construction components can be organised in many ways based on the relationships illustrated in Figure 6. Often, the primary structure is based on the storeys of the building as shown in the following example. The composition structure then starts with the instance of the building class and the next level includes instances of the storey type. The subsequent levels comprise instances of building components. Observe that component types can be used for nodes in order to clarify the content on the next level, see for instance the node 'Walls'.

**Hierarchy 4 – Sample composition hierarchy of building construction components**

**Building**
- Basement
Ground floor
  Walls
    Wall 1
    Wall 2
    Window 1
    Window 2
    Door 1
        Door frame
    ....
  Wall layers
    Layer 1
    Layer 2
    ....
  Floor slabs
    Floor slab 1
    Hatch 1
    ....
  Columns
  Beams
  ....
First floor
  ....

The Danish DBK system [BIPS 2006] proposes another composition hierarchy, where buildings at the top level is divided into systems.

Hierarchy 5 – DBK composition hierarchy of building construction components

Building
  Site system
  Foundation system
  Wall system
        Wall construction
        Window panel
            Window
            Frame
            Pane
            Panel
            Connection
        Door panel
  Slab system
  Roof system
  Water system
  Drainage system
  Gas and air system
  Cooling system
  ....
Such composition structures can form the basis for various kinds of descriptions of a building or a building model, for instance quantities, cost calculations, activities and work instructions. The higher levels of the hierarchy can represent aggregated data, e.g. the sum of cost.

Many other structures can be formed depending on the relationships between building components. If for instance, relationships are created between rooms and the construction components, which demarcate the rooms, such a structure could also be generated.

When operations and maintenance have to planned, the focus is often different. For instance the primary building components have minor importance whereas windows, doors, dormers, bay windows, roofs, etc. are much more important.

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Appendix A

Basic Terms

In order to create classifications for the building construction area, a number of terms are necessary to clarify. Here is a short overview over the most important ones.

Building Component

A building component is a general concept for all major parts of a building (ISO 12006-2: construction entity part). Building components are either spaces or construction components. A building component fulfils a predominating function of the building, either in itself or in combination with other components.

The term component is used here in compliance with general systems theory. A component is part of something, i.e. a component can be considered a part of a larger component (super-component) and each component can be divided into smaller components (sub-components). This basic understanding of the concept is important seen from a modelling viewpoint. A component is very often identified as a major component and will normally be subdivided at later stages of the modelling process. Further in systems theory, an element is a component, which in a certain context is considered not to be further subdivided. Consequently, the use of this term, e.g. in ISO 12006-2 and Industry Foundation Classes (IFC), is confusing compared with systems theory. In CAD systems, it may be reasonable to use the term element about the predefined objects, which CAD systems typically provide in libraries and which can be inserted into a model and combined with other objects to form building models. However, as soon as they are inserted in a model, they must be regarded as components and considered for further detailing.

Space

A space is a part of the built environment. It is at placed in the 3D space and marked off in some way by either physical or abstract boundaries. Spaces can be occupied by people, things, and substances and serve as mediums for activities and movement. A model object of a space can be identified before it is positioned and delineated by boundaries. In the following, only internal spaces of buildings are considered.

Construction Component

A construction component is a building component, which is or is meant to be physically constructed. In a building, spaces and construction components are considered complementary to each other. Predominating functions of construction components are e.g. load bearing, load supporting, enclosing, separating, connecting, and servicing. In the following, construction components will include equipment, installations, furniture, etc.

Analysis

Analysis of some (existing) component is 1) to investigate properties of the component and 2) to divide it into contained components and structure.

Synthesis

Synthesis of some (new) component is 1) to create it by relating existing components to each other by a structure and 2) to add properties to the component.
Abstraction Mechanism
An abstraction mechanism is a method for making abstractions. Two fundamental abstraction mechanisms exist: composition and classification.

Composition
Composition is an abstraction mechanism, which forms hierarchies of objects determined by whole-part relationships. These relationships can be identified by the complementary operations aggregation versus separation.

Classification
Classification is an abstraction mechanism, which forms hierarchies of object classes determined by their properties. Such a hierarchy is termed taxonomy i.e. a hierarchy of object classes showing general-special relationships. Classification supports the identification of model components and structure at a class level.

In the analysis view, a class is defined as a set of objects, which have certain common characteristics. In the synthesis view, classes are defined with name and attributes as a kind of template from which individual components (instances) and structures can be created. Classes in a classification are preferably identified as disjoint types, i.e. no two objects can belong to the same class. When a classification is created, a classification criterion must be selected. This criterion is used, when a type is subdivided into sub-classes and when classes are joined into a super-class.
Appendix B

Citation from Encarta Dictionary

Noun:

1. purpose: an action or use for which something is suited or designed
   - Its function is to collect water.
   - a watch with an alarm function

2. role: an activity or role assigned to somebody or something

3. event: a social gathering or ceremony, especially a formal or official occasion
   - a black-tie function

4. dependent factor: a quality or characteristic that depends upon and varies with another
   - Success is a function of determination and ability.

5. MATHEMATICS variable quantity: a variable quantity whose value depends upon the varying values of other quantities

6. MATHEMATICS correspondence between members of different sets: a relationship between two mathematical sets, in which each member of one set corresponds uniquely to a member of the other set.

7. COMPUT single computer operation: a named and stored basic operation of a computer yielding a single result when invoked.

8. COMPUT computer program's main purpose: the purpose of a computer program or piece of computer equipment, e.g. database management or printing.

Intransitive verb (verb without object):

1. serve purpose: to serve a particular purpose, or perform a particular role
   - hats functioning both as fashion statements and as protection against the sun

2. be in working order: to operate normally, fulfilling a purpose or role
   - When the heart ceases to function, the patient is clinically dead.
Appendix C

The Function Concept

Because the concept *function* in English is both a noun and an intransitive verb, it is important to state that, in this context, only the noun is considered. Therefore, the concept will be used in phrases like "something has/provide a function ...", "something's function is ..." or "the function of something is ...".

As observed, there are several interpretations of the concept ranging from rather concrete meanings to abstract meanings. Moreover, there seems to be contradicting meanings between functions of organisms or machines and inactive objects. Human beings, for instance, can have functions based on what they perform but inactive/passive objects can also have functions even though they perform nothing by themselves. Further, there seem to be a distinction between what already exist and what is to become. So, in addition, it is necessary to define intended functions.

In order to bring forward a definition of the function concept, one distinction is between *active systems* and *passive systems*. Active systems represent living organisms, machines or mechanical things, which can perform operations by themselves or by supply/transformation of energy. Passive systems or objects can not perform operations alone. Another distinction is between *analysis view* and *synthesis view*. In the analysis view, function is expressed about existing systems or objects, while the synthesis view aim at specification of functions for systems or objects to come (modelling). When these distinctions are combined, four different situations appear.

Analytically, the function of an active system can be identified by what it performs, by the transformation that takes place, i.e. input is transformed to output. Sometimes the transformation identifies the function and sometimes the output identifies the function.

Some examples in the analysis view:

<table>
<thead>
<tr>
<th>Active system</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actor</td>
<td>to entertain</td>
</tr>
<tr>
<td>Watch</td>
<td>to show time</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>to cool</td>
</tr>
<tr>
<td>Pump</td>
<td>to produce flow of a liquid</td>
</tr>
<tr>
<td>Apple tree</td>
<td>to grow apple fruit</td>
</tr>
<tr>
<td>River</td>
<td>to transport water</td>
</tr>
</tbody>
</table>

When multiple functions can be identified, a primary function is often selected as the most characteristic function.

<table>
<thead>
<tr>
<th>Active system</th>
<th>Primary function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>to transport people or goods</td>
</tr>
<tr>
<td>Mobile phone</td>
<td>to telecommunicate</td>
</tr>
<tr>
<td>Computer</td>
<td>to execute programs</td>
</tr>
<tr>
<td>Cow</td>
<td>to produce milk</td>
</tr>
</tbody>
</table>

A passive system or object can analytically have one or more functions identified by what it offers when it is used in processes or by what it is actually used for.

<table>
<thead>
<tr>
<th>Passive system/object</th>
<th>Function / primary function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Book</td>
<td>to hold information</td>
</tr>
<tr>
<td>Oil</td>
<td>to give off heat / to oil</td>
</tr>
<tr>
<td>Cave</td>
<td>to shield from weather</td>
</tr>
<tr>
<td>Drinking glass</td>
<td>to contain liquids</td>
</tr>
</tbody>
</table>
Knife to cut

In the synthesis view, a function of a system or object can be identified as what it is suited for or designed for. Hence, model objects can have functions by definition even though they are not (yet) used or take part in any processes. (On the other hand, the actual use of an artefact produced from a model object can be in contrast to the intended function.)

<table>
<thead>
<tr>
<th>Model object</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamp</td>
<td>to give light</td>
</tr>
<tr>
<td>Match</td>
<td>to give fire</td>
</tr>
<tr>
<td>Chair</td>
<td>to provide a seat</td>
</tr>
<tr>
<td>Lift/elevator</td>
<td>to elevate/lower people or goods</td>
</tr>
<tr>
<td>Bath room</td>
<td>to facilitate personal care</td>
</tr>
</tbody>
</table>

To conclude, the definition of the function concept can be divided into four different variants dependent on the following four combinations.

**Definition**

<table>
<thead>
<tr>
<th>Function concept:</th>
<th>Analysis view</th>
<th>Synthesis view</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active system</td>
<td>What it performs</td>
<td>What operations it is designed to do</td>
</tr>
<tr>
<td>Passive system/object</td>
<td>What it is used for</td>
<td>What use it is designed or suited for</td>
</tr>
</tbody>
</table>
Appendix D

Classification Usage Scenario

Classification systems must be usable many times throughout the life phases from requirement specification to operations and maintenance. Obviously, different classification systems will be used differently and with various advantages and disadvantages in the phases. Further, use of different modelling approaches and technologies, e.g. software applications, will have an effect on the outcome. Related to this, it is important to evaluate the efficiency and effectiveness for instance by comparing different approaches and methods and it will be essential that the processes can be beneficially supported by software applications.

In the following, a usage scenario with substantial use of the above sketched classification system is illustrated. The approach is divided into four collections of activities.

1. Specification of functional requirements for a building
2. Creation of Model Objects for Building Construction Components
3. Analysis and Simulation based on Building Models
4. Use of Building Models in Construction and in Operations and Maintenance

Observe that the activities are carried out in a way, which in practice not yet can be supported by existing software applications. However, it is important that the development of a suitable classification system aims at the future possibilities.

In the following, these acronyms are used for the taxonomies: C-F = classification of functions, C-BC = classification of building components and C-P = classification of products.

Specification of Functional Requirements for a Building

Function specification covers many issues but, in this scenario, it is limited to functions of building components, i.e. spaces and building construction components. Some software applications can to various degrees support the selected activities.

![Figure 7 – Use of C-BC and C-F in function specification](image)

Specification of Requirements for Spaces

The taxonomy of functions C-F is directly supporting this task. For instance, before specific spaces are identified, it is easy to create a simple list of functions, which must be provided by the spaces. This can by done by selection of references to entries of C-F.
Examples:

Provide spaces for
- Work, administration
- Sleeping
- Relaxation, reading
- Personal care

Next step could be to develop a space program, i.e. a number of space objects (including rooms) and allocate the identified functions to these spaces. Observe that the space objects are created without location and delineating geometry. As at such an object is created, any number of functions can be allocated by use of the references in the function list or directly to the C-F taxonomy.

Besides that each space object can have attributes like name and description, it can be further specified by formulating different constraints about attributes, e.g. area requirements, requirements about temperature and air conditioning. In addition, requirements about specific building services equipment can be specified by selections from C-BC (building services).

**Specification of Requirements for Building Construction Components**

Similarly, a number of requirements may be formulated for construction components of the building, i.e. before such components have geometry and location. First, a model object is created by selecting a type relatively high in the C-BC hierarchy. The idea is that this object can be specialized later on but it can immediately be specified with functions and the requirements can be formulated, e.g. constraints on the function attributes. Some functional requirements may contribute to requirements for adjacent spaces.

**Creation of Model Objects for Building Construction Components**

Creation of model objects for building construction components is usually well supported by modelling software. Ideally, there should be a connection with the above described activities in which a number of model objects are already created without geometry and location. However, requirement specifications are only available in form of documents and, often, the real building modelling will start with the following activities.

*Figure 8 – Use of C-BC and C-F at creation and specification of model objects*
Automatic Generation of Model Objects for Walls and Floor Slabs

If model objects for spaces are already created and arranged horizontally in a space plan in storages, it may be possible to make an automatic creation of model objects for walls and floor slabs as delineation of the spaces. The types of walls and slabs can be selected from C-BC and the modelling software should be equipped with a library of object types, structured like C-BC. The automatic generated may be changed manually, e.g. wall thickness. An important aspect is that references to entries in C-BC are also created for later use.

Specialisation of Model Objects

The model objects, which have been created as general types in C-BC, can be specialized by selecting a type further down in the sub-tree in C-BC. By this operation, more attributes will be added while the existing attributes will be preserved. It requires that the modelling software application has a library, which is structured like C-BC.

Ordinary Creation of Model Objects for Building Construction Objects

Many building modelling projects start here because this is how the used modelling software works. As already described, model objects, e.g. for walls, columns, and beams, can be created by selecting specific types in C-BC and the attributes of the type will be created at the same time. For later use, the reference to the entry in C-BC is added and an attribute. Again, it requires that the software application has an object type library, which is structured like C-BC. The selected objects are modified and inserted in the model and, automatically, the relationships between model objects are created or updated. For instance, this means that different forms of composition structures can be shown.

Positioning of Space Objects

As already described, model objects for spaces may have been created without geometry and location, so now, if basic objects like wall objects and floor slab objects are created, it will be suitable to locate the space objects to their specific positions. The space geometry should be created automatically along with the relationships.

Space objects, which have not been created and located, can be created the usual way by first selecting a space type in C-BC and then specify the position in the model. The attributes will be created at the same time and they may be modified and assigned values as needed. In addition, space functions can be selected and allocated to the space object by use of the relationships between C-BC and C-F. Further, attributes describing these functions can be added to the objects.

Analysis and Simulation based on Building Models

One of the greatest advantages of building models is the ability to make various data extracts from the models and to perform special analysis tasks. As already mentioned, different sorts of composition structures can be created by using the automatically created relationships between model objects. Regarding analysis, it is often very beneficial to perform a range of calculations based on quantities derived from the models.
Calculation

Different kinds of economy calculations are often very valuable. Early in the process, the calculations are characterised as rough estimates and later on more precise calculations can be achieved. The accuracy of the estimates is depending on how detailed the model is and, thereby, how precise quantities can be extracted.

An important aspect of calculation is that it may be possible to use data, which are available via references to C-BC. These data may be about specific technical solutions, recipes, needs for labour, unit prices, etc. Traditionally, classifications like C-BC have been very detailed and therefore some manual work to make specific selections. Future calculation software applications will be able to make advanced search operations in databases by use of more detailed models. For instance, it will be possible to use model data about material layers, layer thickness, etc. A result of the calculation may be that the model automatically is updated with economy attributes and values so that these data can be extracted subsequently.

Other Kinds of Analysis and Simulation

A range of other analysis operations can be carried out in similar ways with dedicated software applications, which often contain special calculation models and additional data. However, some data must be available in the model before the analysis or simulation can take place. Previously described methods for adding attributes can also be used here. On the other hand, these software applications can also add data to the model as suited. Once again, it is possible to use references from the model objects to C-BC.

Use of Building Models in Construction and in Operations and Maintenance

It is important that building models also can be used when the physical building is constructed and in the subsequent operations and maintenance phases. This means that the model must be detailed further as described previously. Some modelling applications can support this but it may be better to use more dedicated software.
Completion of Building Model for Construction

The existing model objects can via references to C-BC be extended with data about construction recipes, material consumption (including estimates for waste and scrap), needs for equipment, scaffolds, etc. Furthermore, specific data for planning of construction activities can also be attached to the building model.

In connection with this, it will also be useful to select specific commercial products to be built in. This may be specified via first the references to C-BC and further references to C-P. Data about the specific products may be used indirectly or inserted in the model objects.

Completion of Building Model for Operations and Maintenance

For this purpose, it may also be useful to select specific commercial products as described above. Furthermore, it may be very useful to add a range of additional attributes for operations and maintenance. The basis for this is that a wide range of data is published from various data suppliers in the building sector, like knowledge institutions, product manufacturers, etc., and that these data are attached to the taxonomies of the classification system.

A special arrangement may be that data for operations and maintenance are not included in the individual model objects but are attached to groups of equally described objects. Such a group could for instance be a set of equal windows.

Creation of a Building Model for Operations and Maintenance

If a building model does not already exist to be used in operations and maintenance, such a model can of cause be created as described above. However, the degree of detail of a dedicated model will vary because the different building construction components in the physical building demand different requirements for operations and maintenance. For instance, it will often be sufficient to specify data on groups like described above. Individual objects may perhaps be created later on and detailed and specified, when needed. The taxonomies of the classification system will still be able to support the process.